Census of Lingcod Nesting in the Edmonds Underwater Park

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Abstract

Can useful data be collected by volunteers? The question may be partially answered by a continuing census of lingcod nest sites in the Edmonds Underwater Park. Volunteer divers conduct the census to document lingcod reproduction as an indicator of the overall health of the site.

Nearing 30 years old, the Edmonds Underwater Park is one of the oldest marine sanctuaries and is a unique environment in several ways. Habitat consists of many unusual artificial reef features in a lattice of concrete block and rope trails. It is somewhat isolated from natural lingcod habitat. The 27 acre park is also heavily used by recreational scuba divers.

Divers perform surveys using measuring sticks and slates to collect data on the egg masses and the guard fish during the nesting season. Numbered ID tags are used to locate and mark lingcod egg masses for repeat observation. Nest locations are mapped and data are entered on a spreadsheet. Photographic records have been made of many sites. The park typically provides more than 60 nest sites per season. Four years of survey results have been collected.

Among the observations is strong evidence of repeat usage of specific sites. There have also been several instances of repeat use of a site by individual guard fish identified by physical characteristics (scarring). Data has also been collected on predation of eggs, storm damage to egg masses, and stamina of the guard fish over the season.
The surveys are evidence of the capability of a non-professional volunteer team to collect meaningful data.

Introduction

The Edmonds Underwater Park (EU/WP) is located north of Seattle on the eastern shore of Puget Sound (Lat. 47 49.00, Long.122 23.00) in Washington state. The park has been a marine sanctuary since 1970 and is one of the oldest refuges on the Pacific coast. It is also a popular recreational scuba diving site.
While there is widespread concern that rockfish and lingcod are in general decline in Puget Sound, the park has recently been identified as having significantly larger and more abundant quantities of these fish than other areas (Palsson and Pacunski 1995). Prior to 1970 the area was virtually barren of lingcod and rockfish (personal observation).

The park is maintained by a team of volunteer divers. The divers have been gathering data documenting lingcod nesting activity in the park for the past five years.

Selection of lingcod reproduction as the subject of the surveys is based on the premise that the success of an important predator species is an indicator of the health of the entire local ecosystem. The conspicuous white egg masses and aggressive behavior of the nest guarding male lingcod make the task straightforward and achievable by unsophisticated means.

Purpose

The census is intended to establish a baseline of data as a reference point for the future. The data provide a record to evaluate the effect of physical and biological changes as well as successes and failures of resource management practices. An attempt will be made to identify the factors that are attractive to fish and marine life as a guide to future enhancements. The census will also validate the capability of a volunteer team to produce legitimate data.

Prior investigations of lingcod spawning activity (Jewell 1968), (Low and Beamish 1978), (LaRiviere and others 1981) and (Giorgi 1981) are succinctly summarized by Cass and others (1990). O'Connell (1993) investigated deepwater spawning in Alaska. Unique aspects of the subject study are the sustained time period involved and the artificial habitat in which the lingcod spawn. The method used in the study was patterned after surveys by the Vancouver Aquarium in Howe Sound, B.C. Canada (Martell 1997) and have been adapted for use as a census in this study.

History

The nearshore of Puget Sound in the vicinity of the underwater park is primarily sandy bottom. A region of cobble and glacial erratic rock north of the park provides anchorage for a kelp bed in the summer months. At the turn of the last century, saw mills were located at the site of the park and the substrate is still infused with woody debris. Manmade structures in the area south of the park includes the oil pier at Edwards Pt., the breakwater at the Edmonds Marina, and the Edmonds Ferry Terminal. In the late 1970s, a fishing pier that included artificial tire reefs was built. In the mid-1930s a derelict metal dry dock was sunk just north of the ferry terminal. This was supplemented in 1971 by the wooden hull of the motor vessel, Alitak, on the shoreward side.

Since 1979 structures have been added within the park to provide interest to divers and to enhance the marine habitat. The added features are arranged as isolated structures on the sand bottom in an "oasis" pattern. Materials used include stone and concrete rubble, concrete beams and arches, concrete and plastic pipe, large hollow concrete blocks, and a variety of boat hulls. The Edmonds Underwater Park and surrounding area are geographically isolated from the rocky reef habitat usually associated with lingcod.

Materials and Methods

Volunteers divers conducted field work observations on weekends, primarily Saturdays. Participating divers were divided into teams and each team surveyed a portion of the park. A flexible rotation schedule insured that all portions of the park were visited on a regular basis, several times within the maturation period of a viable egg mass.

Divers performed surveys using standard scuba equipment. All dives originated from shore. Divers located and marked each egg mass in the park. A numbered plastic tag was affixed near each new nest site when the eggs were first detected. If a convenient attachment was not available, a plastic stake was inserted in the sand and the tag was affixed to the stake. The tags were white with black lettering and were attached with nylon tie wraps. These tags were intended to last for one spawning season and were replaced each year.

All of the data was from *in situ* visual observations. Simple tools were used to collect data about the nest site, the egg mass, and the guard fish.

A standard format slate was used to record the data (appendix a). Survey parameters have been standardized to encourage consistency of observations. The slate has a legend of the standard terms/attributes. A sheet of instructions (appendix b) was provided to assist the volunteer diver in recording consistent data.

A narrative description of the nest site was made. The description was sufficiently detailed to locate the nest site on a map. A nest site is defined to be the territory defended by the male guard fish.

The egg mass is a contiguous volume of eggs. There may be more than one egg mass at a nest site. The size of the egg mass and color of the eggs were recorded. The size of the egg mass was defined as the overall dimensions, the size of the rectangular box that would contain the mass

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Freshly spawned eggs have a pearly pink hue. In about a week the eggs turn pure white. In later weeks the eggs become a dull opaque white. After four weeks the eggs will have a gray tone, often with non-uniform coloration from egg to egg. The older eggs may have broken shells and be discolored by diatom/fungal growth.

Information descriptive of the nest site was recorded by specific standardized parameters and by general comments. The standard parameters included the height of the egg mass off of the substrate, the material upon which the eggs were deposited and the geometric characteristics of the cavity occupied by the egg mass. A cavity was judged to be sandwich or wedge shaped. Sandwich indicates approximately parallel sides; wedge indicates a wedge-like cavity. A kebob nest is spawned onto the retaining material encasing it as though skewered, like a kebob. The egg mass cavity was further categorized by orientation of the long dimension, either horizontal or vertical.

Guard fish parameters that were recorded include the overall length of the fish measured to the nearest 5 centimeters with a measuring stick. The color of the fish was noted. The standard color characteristics are: light, dark, mottled and brownish. Combinations of mottled and one of the other color characteristics were allowed. The behavior of the guard fish was also noted. The fish was called passive if no aggressive motion was made toward the observer. A single aggressive display or threat to the observer was said to be aggressive, repeated aggression or threats were termed very aggressive.

Information was also recorded on predation of the egg mass. The physical appearance of the guard fish was checked for markings such as scars and healed wounds that might serve as identification of individual fish. These and other unique characteristics were noted in the comment section.

After the dive the slates were copied on a copy machine and filed in a three-ring binder, retaining the field notes for future reference. The data was transferred to a spreadsheet database. The locations of nest sites were plotted on a map.

In addition to the slate, tools used by survey divers included a 1 meter-long staff of plastic pipe graduated in 10 centimeter increments used to aid in measurements. Photographs and occasionally video, supplemented the data. An underwater light and magnifying glass were useful in observing the eggs. Fiberglass tape measures were used to measure distances for site locations for mapping purposes.

In addition to the seasonal plastic tag, previously used locations are in the process of being marked with a permanent identification number. These numbers are intended to stay with the site from season to season. Smaller brass and plastic tags with numbers stamped into the tag surface are used for these markers (both plastic and brass were used to determine which is more permanent). Permanent tags are attached using tie wraps embedded in underwater epoxy after the spawning season.

Results and Observations

The survey effort is summarized by season in Table 1. An observation is defined as visiting a nest site and recording data. The total number of divers that participated each season is also shown.

Table 1. Survey effort by season

	Season			
	96/97	**97/98**	**98/99**	**99/00**
Effort:				
Dives	**31**	**68**	**76**	**61**
Observations	**109**	**182**	**215**	**335**
Divers	**11**	**24**	**14**	**14**

Data on the egg masses is presented in Table 2. The chart compares the number of egg masses, the number of those that are repeat locations from the prior year, the average volume of the egg mass and the date the first nest of the season was found. About 40 % of the egg masses were in the same location as the previous

season. The observed size of the egg mass was the overall dimensions of the egg mass, the actual volume of eggs is less. A volumetric coefficient of .5 is appropriate to get an approximation of the actual volume of eggs. The first egg mass was usually found about the third week of December.

Table 2. Egg mass information by season

	Season			
Egg Mass	**96/97**	**97/98**	**98/99**	**99/00**
# of Nests measured	**30**	**48**	**59**	**87**
# Repeat sites	**----**	**13**	**19**	**26**
Avg. Volume (cm^3)	**12,500**	**20,600**	**11,800**	**13,400**
First nest seen (date)	**12/23/96**	**12/20/97**	**12/19/98**	**11/27/99**

Figure 1 plots the number of new egg masses found each week over the length of the 1997-1998 season, starting at the first sighting. The comparison of nesting rate from season to season will indicate if there is a pattern. Color is a useful means of determining the approximate age of an egg mass. Freshly spawned eggs are a pearly pink color that changes to white and then dulls over the maturing period. The description of color change of the eggs is generally consistent with prior observations (Wilby 1937). The recorded color of the eggs can be used as an adjustment to the observation date to provide an approximate spawning date. This is being considered for future measures.

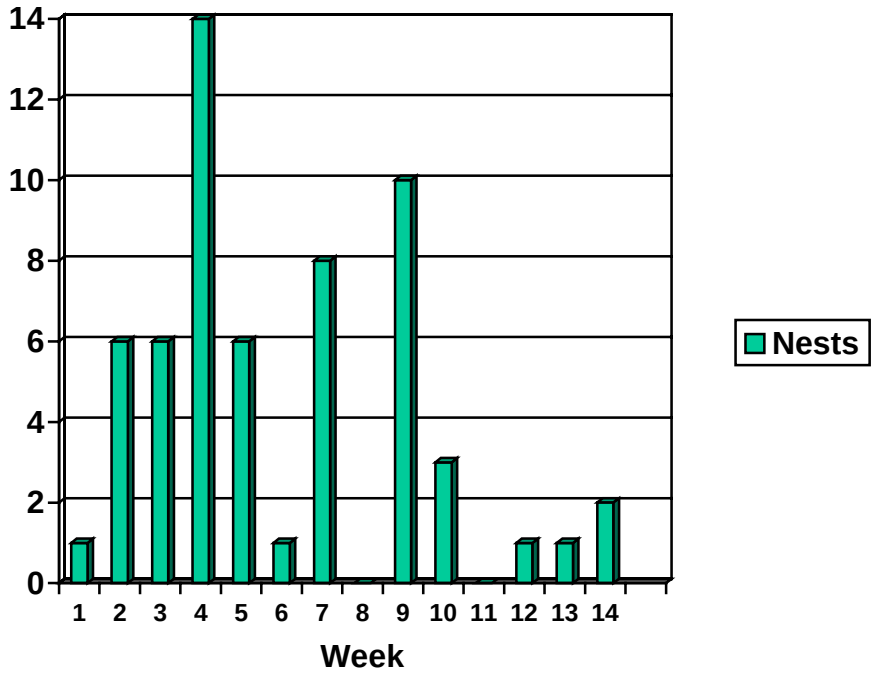

Figure 1. Number of nests found per week during the 1997/98 nesting season

Figure 2 compares guard fish length over the seasons. Guard fish are grouped in 5-cm increments on the horizontal axis. The number of guard fish is shown on the vertical axis. A fairly consistent distribution of length is shown, indicating that younger fish are being recruited each season. The average length of the guard fish is just under 80 cm.

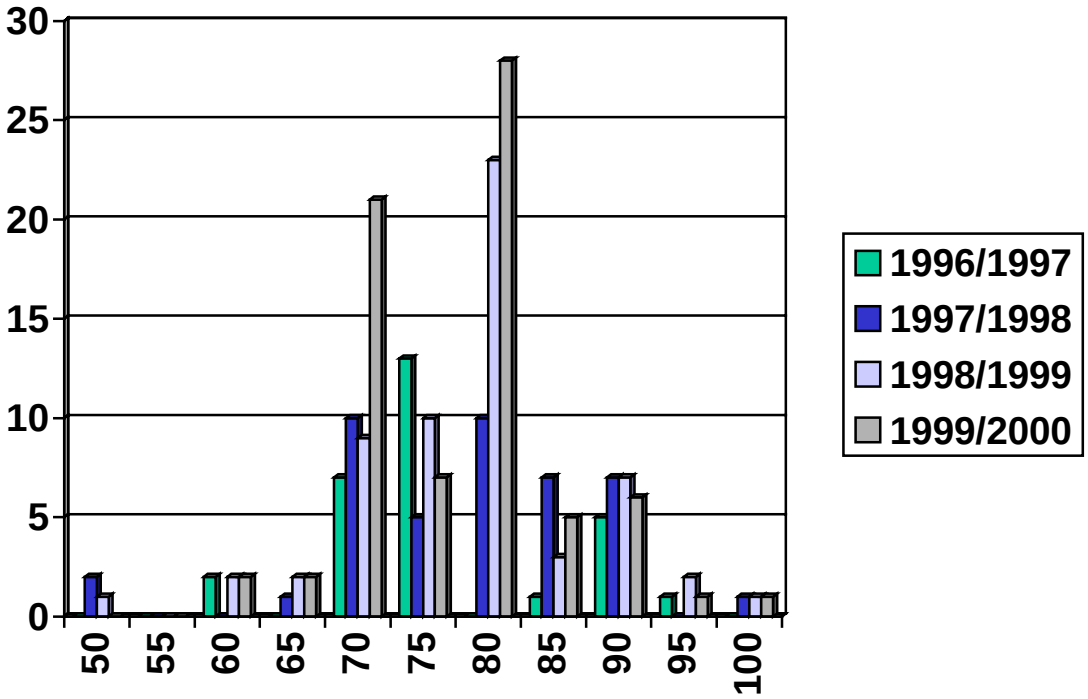

Figure 2. Distribution of guard fish by length (cm) in four seasons of observation

The data of these tables and figures will be used as a baseline for future comparison.

A temperature recording probe was placed in the park for the 1999-2000 spawning season. It was programmed to provide temperature variation over the nesting season. It is planned to continue use of the probe in subsequent seasons to see if a relationship exists between temperature and spawning activity.

Discussion

Methods

Several changes were identified and implemented as improvements to the survey techniques. The method of marking nest sites has seen the most changes. Initially round flat beach rock painted and numbered were used. These were placed near the nest site and oriented with the number readable while pointed toward the egg mass. The material for the markers was readily available and the markers were easy to make and use. The problem was that the guard fish didn't like them and the recreational divers did. Observations were complicated by the markers not being visible either because guard fish had batted them around until they turned over (and looked like a beach rock again) or because divers had carried them off as souvenirs. Other methods that were tried included numbered pieces of white PVC pipe tied in place and numbered strips of fluorescent green survey tape. These were cumbersome to deal with underwater and took to much time to tie in place. The current method using white plastic tags is visible enough to be readily seen by survey divers, aren't disturbed by divers visiting the park, and don't upset the fish.

The technique of measuring fish with the graduated staff often involved selecting points on the substrate near the nose and tail of the fish and measuring the distance after the fish had moved. The method is considered to be accurate to within plus or minus 5 cm.

A schematic diagram of the park was initially used to plot the nest sites. While this was adequate it was recognized that a more accurate map would be more useful. Considerable effort was expended producing a map of the area. It has also been found useful to create smaller local diagrams to supplement the larger map.

The first season an attempt was made to recruit volunteer divers to do the surveys; in subsequent seasons participating divers were either returning from previous seasons or came forward on their own. Recruiting volunteer divers was found to be somewhat inefficient in that the divers who responded were of uncertain skill and commitment. Those that expend the effort to make themselves known are typically more interested and involved. Fortunately sufficient numbers have volunteered to collect consistent data throughout the study. Experience indicates that 12 qualified, capable volunteer divers are adequate to do the census.

Substrate

There did not seem to be any particular substrate material that was refused by spawning fish. A variety of different materials, both natural and artificial, were available and were used. There also does not appear to have been a preference in the orientation or geometry of the cavity selected for the egg mass. The average height of the nesting cavity selected in the census was 77 cm above the sand bottom due to artificial structures. The “perfect” nest site, based on information from the census, would have a 10 to 20 cm wide wedge or parallel sided cavity with rough facing surfaces for retaining the egg mass and be located 80 cm from the bottom.

Quantity of Egg Masses

The number of egg masses increased each season of the census. This was in part a measure of the increased skill of the survey divers. The initial season (1996-1997), a portion of the park was not surveyed. Another factor was the increase in potential nest sites from year to year. New features in the park typically host new nest sites immediately.

Winter storms were a significant cause of egg loss in the Edmonds Underwater Park. It was typical to see loose egg masses after a storm. The park has exposed shoreline and the artificial habitat is in shallow water subjecting nest sites to surge and wave effects.

Guard Fish

It was not unusual for a male lingcod to guard more than a single egg mass. This is consistent with earlier observations. There have been instances of a fish defending three egg masses and one fish was guarding four egg masses in the underwater park. The greatest distance observed between egg masses defended by a single fish was 25 feet. There have been many cases where males guarding eggs in adjacent territories had egg masses less than 10 feet apart, the shortest distance measured was 4 feet. This small distance between adjoining territories may have been influenced by the nature of the artificial features in the underwater park.

Guard fish displayed a varying degree of aggressiveness toward the survey divers. The aggressive behavior described by LaRiviere and others (1981) was common in the park. In the reference the described behavior is attributed always to large (80+ cm) guard fish. In the underwater park several guard fish in the 70 cm range have also demonstrated very aggressive behavior. Very aggressive guard fish in the underwater park have bumped and bitten survey divers. No divers have been injured but one dry suit was punctured. The more aggressive behavior of guard fish in the park may be due in part to their increased familiarity with divers. There may be a correlation between guard fish guarding multiple egg masses and very aggressive behavior, this will be examined in future surveys. The male fish in the park usually exhibited more torn fins, scrapes, and sometimes wounds, than fish observed in natural habitat. This may be due in part to the stress of frequent diver encounters, the high population density and the presence of sharp metal edges of

deteriorating structures. Aggression by other fish and rock scratches are also suggested as sources of head scarring (O'Connell 1993). The aggressive tendencies of individual guard fish tended to decrease over the nesting period.

The propensity of the guard fish to sustain injuries yielded an unexpected benefit to the census takers. Scarring from healed wounds enabled identification of four individual male lingcod from season to season. These males were christened with names consistent with their physical characteristics. Split Lip (believed to be deceased) had a distinctive vertical scar of the lower lip. Jack (One-eyed Jack) lost his left eyeball. Bob (Bobtail) has a portion of the upper portion of his caudal fin missing and Max has a portion of his right maxillary missing. These males have defended the same territory from season to season and have used the same cavity for egg masses (Table 3). Many of the other nest sites used in repeat years have guard fish with increasing length measurements from year to year raising the possibility of the same guard fish returning to the site.

Table 3. Visually distinct individual male guard fish

	Season			
Individual fish	**97/98**	**98/99**	**99/00**	**00/01**
Split Lip	**X**	**X**	**<1>**	
Jack		**X**	**<2>**	**<2>**
Max		**X**	**X**	**X<3>**
Bob		**X<4>**	**X**	**X**

Notes: X= Nest in same location

<1> Believed deceased
<2> Fish on site, no nest
<3> New site 15 ft. south
<4> First site 10 ft. north

Spawning

Spawning is observed and described on one occasion (Wilby 1937), the time of day is not mentioned. Other studies speculate that spawning takes place at night. Spawning by one pair of lingcod was observed in the underwater park. The event took place between 10 and 11 a.m. on an overcast day. Underwater visibility was approximately 10 to 15 feet horizontally. The spawning fish were estimated to be 60 to 70 cm in length. Fertilization was not observed and probably did not take place since spawning was interrupted by the observer. A photograph was made of the spawning fish (see Photograph 1). The egg mass was missing one week later and the male had abandoned the site.

Photograph 1. Spawning lingcod, the female is on her side under the concrete footer. A portion of the egg mass is visible in the horizontal wedge cavity. The male is in the foreground.

Several sources cite the adhesive properties on lingcod eggs to each other and the substrate. Census observations agreed with Giorgi (1981) that while the eggs adhered to each other, they did not adhere to the substrate. They depended on the surface roughness and cavity geometry to mechanically lock the eggs in place.

Egg Loss

Over the period of the spawning season portions of egg masses came loose to rest on the bottom. This was due to the shrinking of the egg mass as larvae hatched combined with turbulent water conditions. Survival of the embryos was largely dependent upon the egg mass remaining in the vicinity of the nest site. If the egg mass stayed within the territory of the guard fish, he usually would continue to guard the eggs. In one instance a fish was seen moving back and forth from the original nest site to an egg mass drifting away in the surge. The following day the egg mass had been abandoned by the male and was located approximately 30 feet away from the original nest site. The egg mass was retrieved and replaced at the original site, skewered and retained by a bamboo garden stake. The guard fish returned to the egg mass when it was replaced within his territory and resumed his vigil.

Predation

Predation on the egg masses as described is consistent with observations of this census. On two occasions guard fish were seen carrying sea stars *Evasterias troschelli* 20-plus feet away from the nest site, which they dropped to the bottom before returning to the nest site. Sea stars *Pycnopodia helianthoides* have been observed engulfing egg masses.

Shrimp are one predator that have not been mentioned in the literature. Most egg masses in the underwater park had shrimp on them and shrimp were observed carrying away small clusters of eggs and picking emerging larvae from an egg mass and consuming them.

Interesting Observations

In the later stages of the spawning season, guard fish have been observed with what may be a parasitic infestation. Small (5 mm) forked tail crustacean-like organisms were observed attached to guard fish. The organisms were not permanently attached, they were able to move about on the fish. The maximum density observed was 2 per square cm. One fish was hosting an estimated 100 of the creatures. The fish exhibited no apparent ill effects from the presence of the organisms.

Lingcod have been seen laying in a depression in the sand away from the features. The depression typically was 60 to 90 cm in diameter and up to 30 cm deep. This typically was observed before the spawning season. It is not known if the cavity was made by the fish.

Another interesting behavior that has been observed is the fish laying partly on one side with the gill cover extended and mouth open in a near trance-like state. It has been suggested that the behavior is similar to that of fish being "cleaned" of parasites in tropical waters. Two observers have reported small shrimp-like organisms being expelled by the fish in a gasping like action as the fish became more alert.

In the underwater park the time after the spawning season was used by the young adult lingcod in the 50 cm length range to recruit into the area occupied by larger fish. The recruiting fish would commonly take up residence on one of the smaller features at a distance from the larger structures. Plastic milk crates used as trail markers on one of the trails were a popular "starter home."

Conclusions

Although it appears that a stable breeding population of lingcod is established in the park, early data looks promising; it is to early to draw conclusions. Sufficient data has been gathered to provide a baseline for future monitoring. A method and protocol have been established that works with volunteer divers.

The survey can be done by volunteers and a volunteer team can produce valid data efficiently. There is an untapped resource available for certain tasks in the right situation using volunteers. The task should be simple and well defined. A champion is needed to organize for continuity and focus. The cost is a fraction of what would be required for a professional team. A volunteer team frees the professionals to do research.

For the future, nest sites will continue to be permanently marked with numbered brass tags. This will simplify defining the locations from year to year. Work will continue on more detailed mapping of park features. An effort is underway to improve the database and simplify data entry and recovery.

Further Research and Investigation

Many questions are raised by the information gleaned to date. Do female lingcod return to the same site the way the males do? Do females spawn all at once or in multiple egg masses? Do males select a territory for life, or upgrade? Are the fish in the park more susceptible to predation? Has the park reached saturation density of lingcod? What is the maximum lingcod population, what is the optimum population? Finding the answers to these questions requires more sophisticated tools, such as tagging fish and DNA analysis, than are available to the volunteer divers.

The census has been an enjoyable learning experience. There is much more to do; effort to date has only scratched the surface of what can be done. The team intends to continue the effort.

Acknowledgments

The census would not have been possible without the dedication and hard work of the volunteer dive team. Steve Martell, with the Vancouver Aquarium at the time, was generous with information about the methodology of the lingcod survey in Howe Sound. Tony Parra, of Washington Department of Fish and Wildlife (WDFW), offered early hands-on advice and encouragement. Ray Buckley, Mary Lou Mills, and Wayne Palsson (WFDW) also provided advice and encouragement. Dave Rockwell and John Williams provided video records of survey activities. Bruce Higgins and Ken Collins helped to set up database structure and generate data for the census. Thanks are due to all of the above.

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Appendix A. Standard format slate.

Date_____ Observers _____,_____ _____ Page_____

****

I.D. # New/Repeat Location_____

N R _____

Guard Fish, Color: L D M B Length: _____cm Behavior: VA A P

Nest Type Ht off bottom Egg Mass(cm) Color Base Material

H V S W K _____cm _____X_____X_____ _____ C M P S R sand ____

Site Description_____

Comment_____

_____

****

LEGEND:

Nest type:	Base Material:	Color:	Behavior:
H= Horizontal	C= Concrete	L= Light	A= Aggressive
V= Vertical	M= Metal	D= Dark	P= Passive
S= Sandwich	P= Plastic	M= Mottled	
W= Wedge	S= Stone	B= Brownish	
K= Kebob	R= Rubber		

Appendix B.Instructions for Filling Out Survey Form

ID #: Number of the location marker. Markers are numbered white plastic placards tied in place at the nest site or attached white plastic tube stake in the sand at the nest site. The placards are about 1 ½ X 2 inches and read “survey site, do not disturb”.

New/Repeat: If the site is newly found, circle the N. and attach a numbered placard near the egg mass. If practical, orient the marker so a person reading the number is facing the nest. Record the number. If the site has already been marked, circle R for a repeat observation.

Location: Describe the site relative to known landmarks, i.e. trails, so it can be found again. Include measured distances to known references if possible. If the site has been permanently marked, record the number stamped on the brass tag. Location not needed for repeat observations.

If a guard fish is not present, so note in the comments. Record the color, length, and behavior of the guard fish. The letters for color are; L = light, D = dark , M = mottled, and B = brownish. Measure the length of the fish to the nearest 10 centimeters. The letters for behavior are; VA = very aggressive, A = aggressive, and P = passive. If the fish does not move toward the observer, consider it passive. If the fish flares its gill plates or moves toward the observer, consider it aggressive. Repeated moves toward the observer is very aggressive behavior.

Nest type: circle the appropriate letters to describe the nest; H= horizontal,
V= vertical, S= sandwich, W =wedge, K= kabob. Use your judgment .

Ht off bottom: Measure and record the distance from the bottom of the egg mass to the substrate in centimeters to the nearest 10 centimeters.

Egg Mass: measure and record the approximate dimensions of the egg mass to the nearest 10 centimeters. The dimensions are of the box in which the eggs would fit.

Color: record the color of the egg mass on the day of observation, i.e., pink, , pearly, pure white, white, opaque white, off white, gray.

Base Material: define the type of material or materials to which the nest is attached with the appropriate letters; C= concrete, M = metal, P = plastic, S = stone, R = rubber, sand, or fill in for other materials. This information not needed for repeat observations.

Site Description: describe the immediate area around the nest and the nest itself.

Comment: Record any unique aspects of the site such as multiple egg masses or fish guarding more than one nest. Note egg predation and presence of parasites on guard fish. Record any identifiable marks on the fish. Record if a photo is taken.

It is OK to leave parts blank if you are unsure, some of the information is not needed for repeat observations, unless things have changed. Try to do the observation with minimum impact to the site, this is a stressful time for the guard fish. Remember one accurate set of data is worth more than 10 that aren’t.

Above all, Keep It Safe & Simple. Have fun!